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Global Lower-Tropospheric Measurements of CO_2 with AIRS

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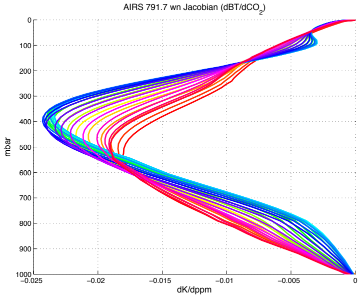
Overview

- Try to sense as low in the atmosphere as possible. Complements Chahine's 250 mbar retrievals.



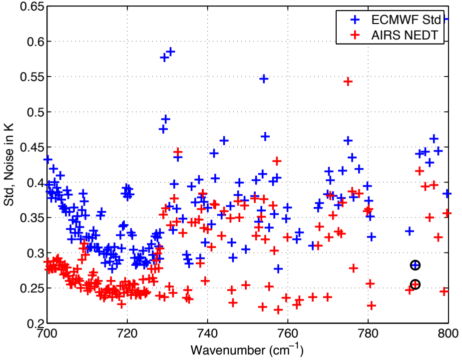
- Must handle surface carefully.
- Clear only. May try cloud-cleared radiances in the future.
- Ocean zonal CO_2 derived using this algorithm extensively validated in our 2007 JGR paper.
- This work: Validate land CO_2 measurements. Nominal reporting grid is 1-2 months, 5 degree grid boxes.

Data

- FOV Selection
  - Used AIRS ACDS clear FOVs
  - Removed about 7% of FOVS due to cirrus
  - ECMWF (with adjustments) used for atmospheric state.
- Atmospheric State
  - Atmospheric state from ECMWF adjusted for T_{sfc} and total column water. Some FOVs removed due to poor water vapor.
  - Sea surface emissivity - Masuda. Land surface emissivity: UW MODIS-based model.
  - Further adjustments to the ϵT_s product done simultaneously with CO_2 retrieval.

How Good is ECMWF?

- ECMWF strongly ties temperature to sondes, dynamic bias adjustment procedure applied to satellite data
- Difference of Std of bias between AIRS and ECMWF and AIRS NEDT is ∼0.03 to 0.05K, equivalent to ∼ 1-2 ppm of CO_2.



CO_2 Retrieval

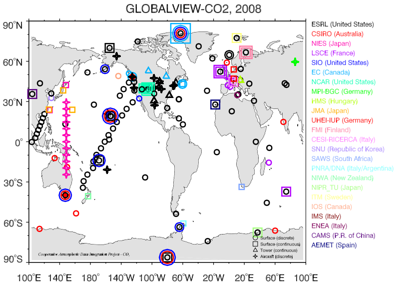
- $790 cm^{-1}$ (surface channel, no CO_2 sensitivity)
- $791 cm^{-1}$ (temperature insensitive CO_2 channel)

$$\begin{aligned} B_{obs}^{790} - B_{calc}^{790} &= J_{T_s}^{790} \delta T_s \\ B_{obs}^{791} - B_{calc}^{791} &= J_{T_s}^{791} \delta T_s + J_{CO_2}^{791} \delta CO_2 \end{aligned}$$

- Assume emissivity constant between 790 and 791 cm^{-1}.
- Jacobians J computed for each FOV
- CO_2 also retrieved similarly using SW channels (2395 cm^{-1} region). These are much more temperature sensitive and provide a diagnostic on errors in ECMWF T(z).

Bias Adjustment Needed for LW and SW CO_2 Retrieval

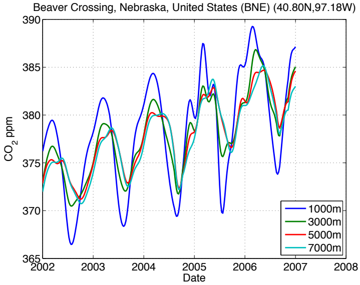
- Spectroscopy plus radiometric errors could easily reach 5-10 ppm
- Used NOAA's GlobalView data set

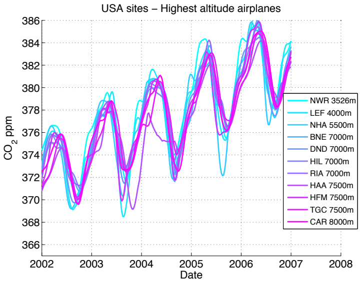


- 400-500 mbar sensitivity limited validation to 11 aircraft sites (all US). Hope to find more validation data sets in Russia, Amazonia.

NOAA's GlobalView Aircraft Sites

- Limited CO_2 profile information even with aircraft sites.
- Simple approach; use the highest altitude flight only (usually 5-8 km).
- GlobalView smooths the raw data. Form time series → and linearly interpolate to AIRS measurement times. Coincidence criteria: 4 degrees lat/lon and 4 days.





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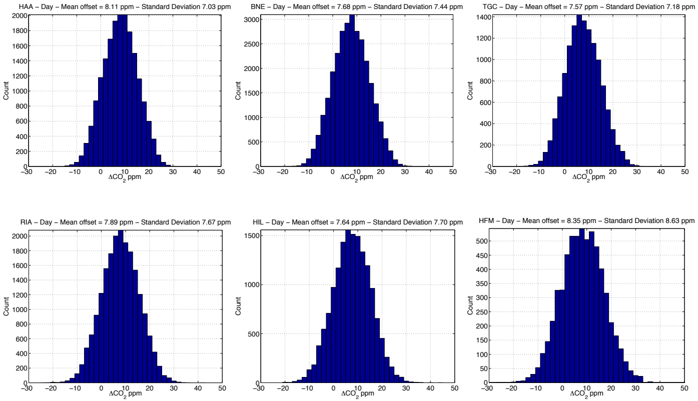
Sample Histograms of Obs-Calc CO_2, Day

Std due to AIRS Noise should be 7-9 ppm CO_2



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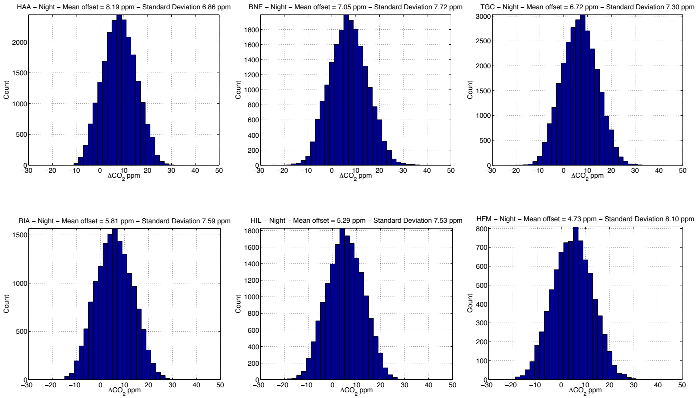
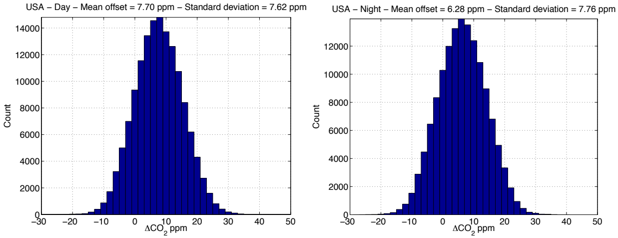
Sample Histograms of Obs-Calc CO_2, Night



Bias Calibration



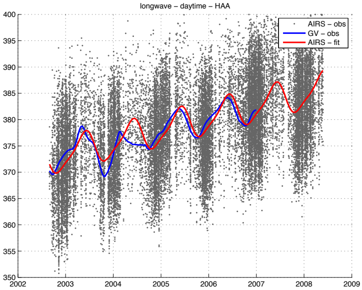
- Errors appear to be relatively gaussian
- Mean bias derived from ~200-500 AIRS FOVs per site
- Daytime (Nighttime) Bias: 7.70 (6.28) ppm
- Individual site Std: ~6 ppm.
- Uncertainty = (mean over 11 sites)/$\sqrt{11} \approx 0.4 ppm$. Roughly the same as single site statistical uncertainty. Too low; US only sites too homogeneous.

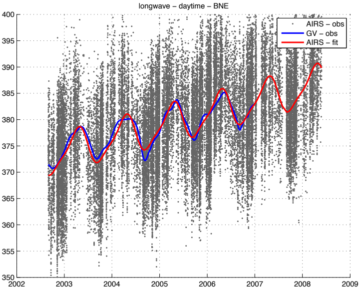
Time series

- Hard to examine AIRS versus aircraft CO_2 time series since single FOV noise high.
- So, fit AIRS data with the a simle function:

$$f(t) = A + Rt + C_1 \sin(\omega_y t + \phi_1) + C_2 \sin(2\omega_y t + \phi_2),$$

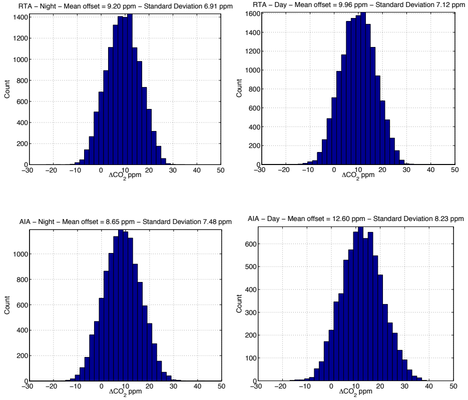
- Two examples: HAA (7500 m) and BNE (7000 m)





Southern Hemisphere Independent Data Set

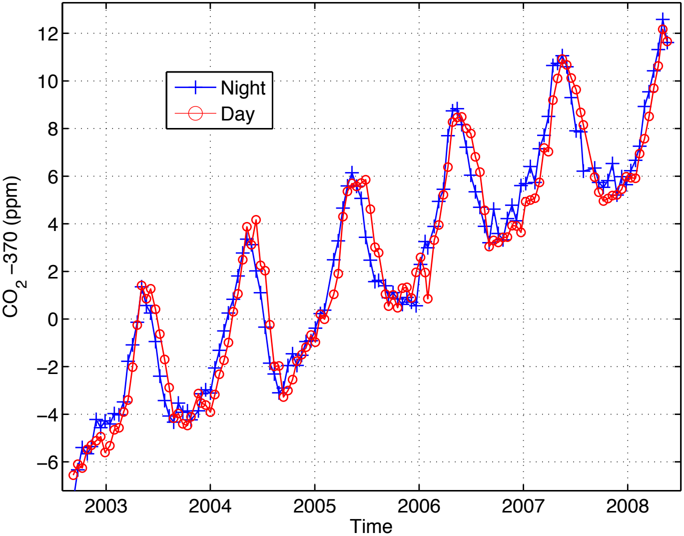
Rarotonga, Cook Islands (RTA) - Cape Grim, Tasmania, Australia (AIA)



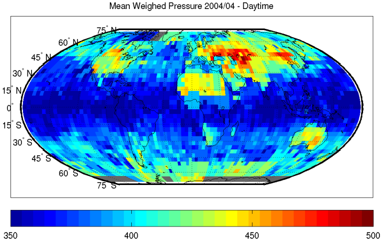
RTA: 4500 m, ocean, good agreement AIA: 6500 m, daytime bias implies we are a few ppm low

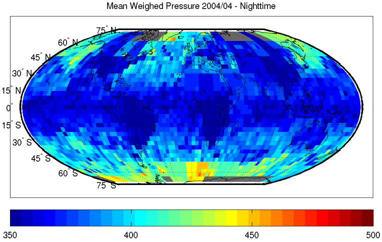
AIRS Trends

Northern Hemisphere (30-50 deg) zonal avg



Jacobians - Day and Night differences





- Weighed mean of the pressure field - using the calculated Jacobians as the weighing function.
- Overall, Daytime sees lower over continental areas.
- Fill in blancks with surrounding averaged data (Sahara/Poles).
- For now we use night only climatological Jacobians for CT comparisons

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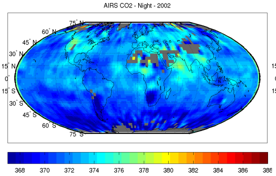
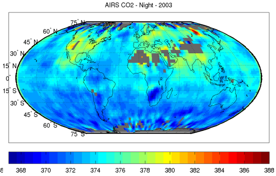
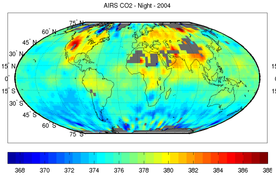
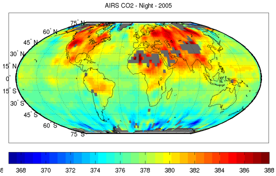
Yearly mean (Fall to Fall) - 2002 to 2006

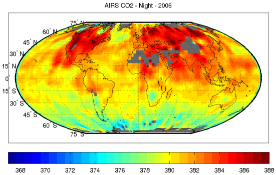
CO2 mean over all 5 years



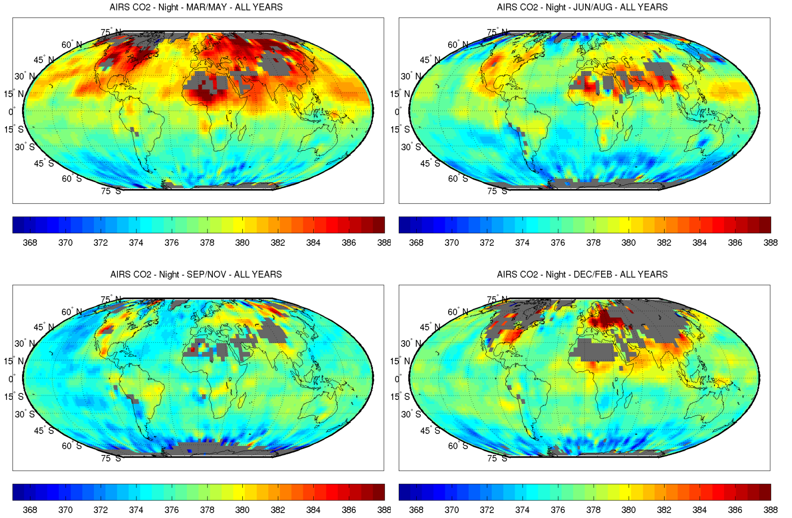






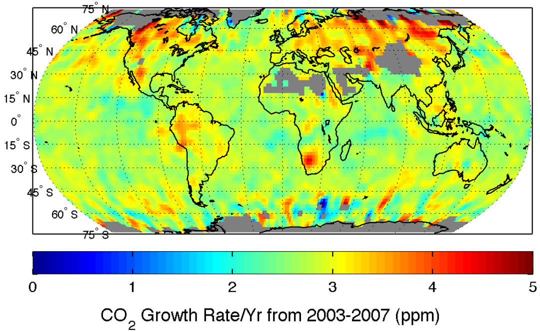


5-Year Seasonal Mean



AIRS Growth Rate

Very rough estimate, just raw differences



- Mean is around 2.5ppm/year
- Will fit each grid point to rate equation in future
- Higher rates for high-latitude land? Southern Africa anomaly is Kalahari Desert - will investigate.

AIRS versus NOAA's CarbonTracker

- Carbontracker - NOAA's asimilated CO2 transport model. Uses GobalView data as ingest.
- Data is in 4D form - We average in time and interpolate to AIRS pressure levels before applying our measurement weighting function.

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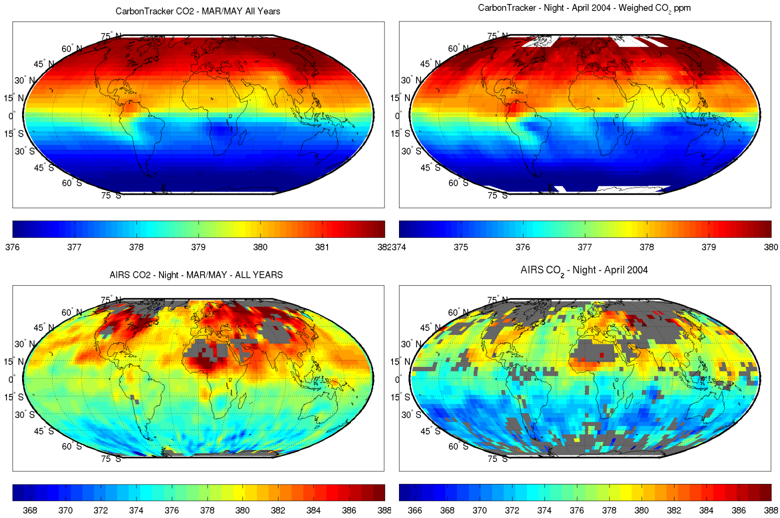
Error in Using Zonal Jacobian Climatology

Left: Zonal climatology, Right: Actual Jacobians



Climatology for Jacobians introduces 1-2 ppm errors. Will fix.

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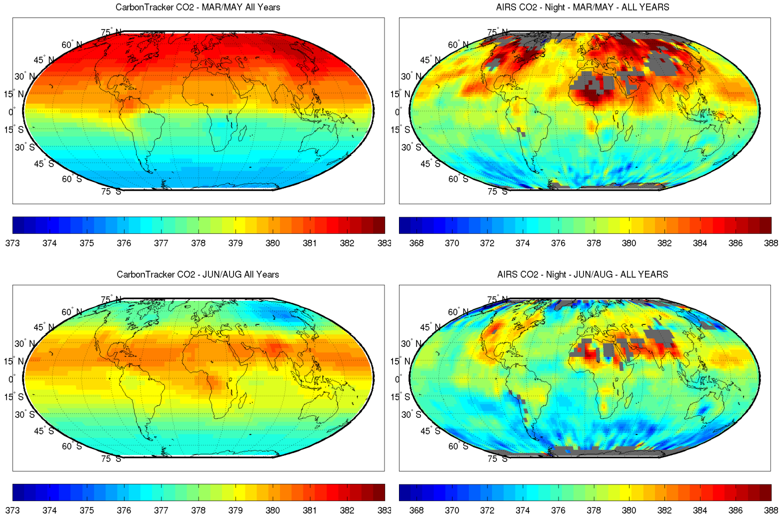
5-Year seasonal mean - Spring - Summer



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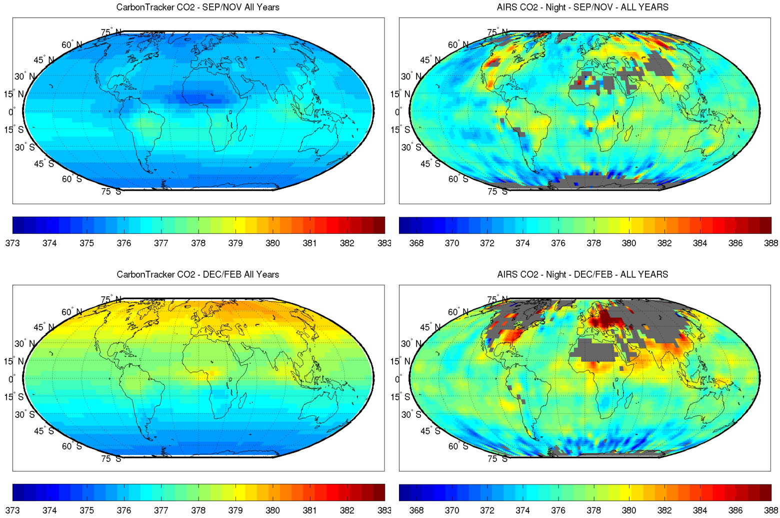
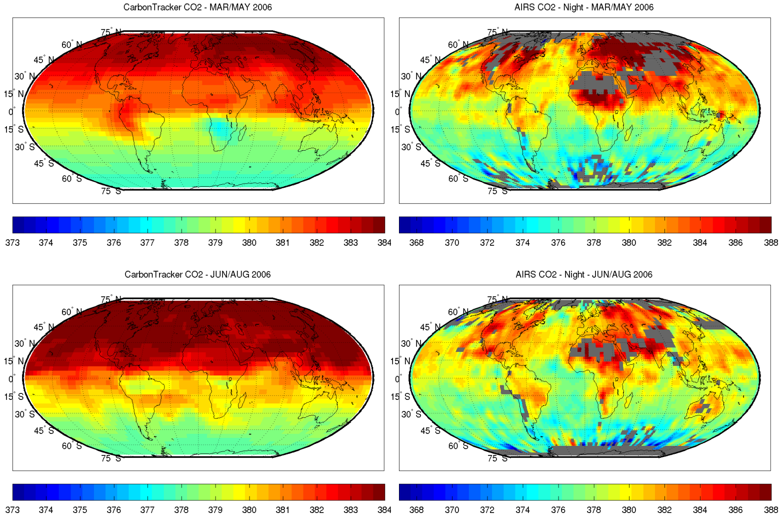
5-Year seasonal mean - Fall - Winter



Seasonal Cycle of Year 2006 - Spring - Summer



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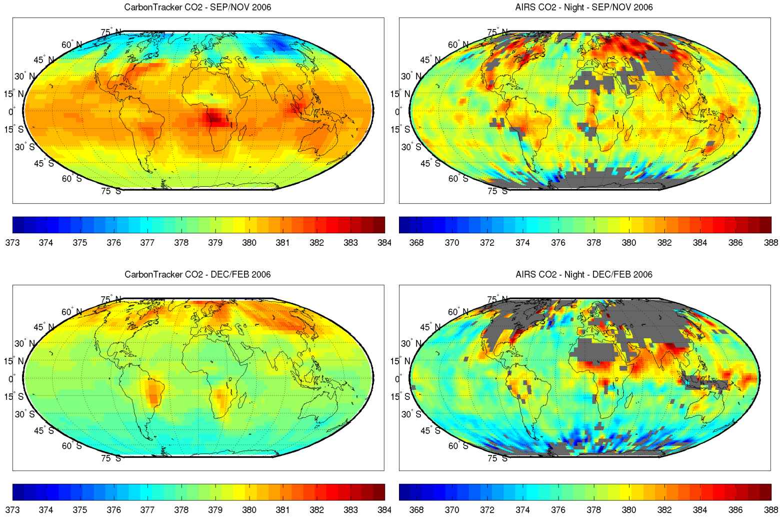
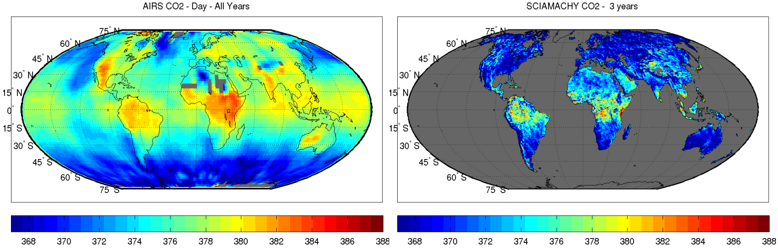
Seasonal Cycle of Year 2006 - Fall - Winter



AIRS and Schiamachy

Scimachy - near IR - daytime only.



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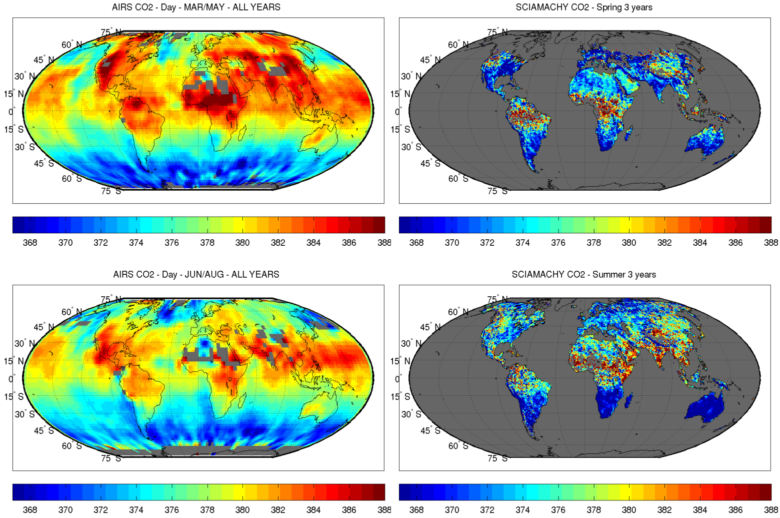
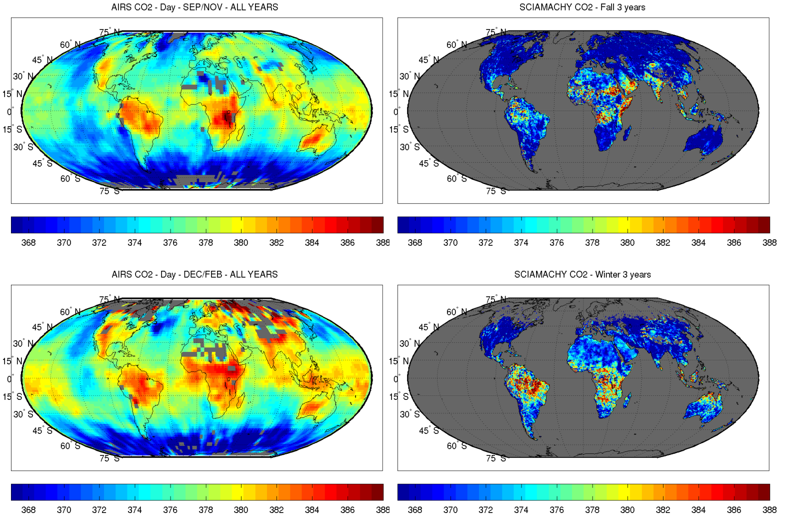
5-Year seasonal mean - Spring/Summer



5-Year seasonal mean - Fall/Winter

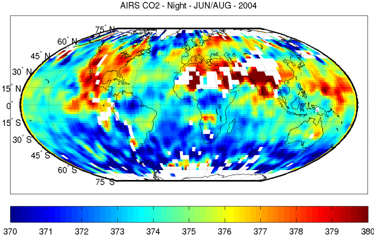


Outlook

- Very encouraging results
- Not discussed: AIRS SW versus LW differences suggest that ECMWF errors are equivalent to $\sim$1 ppm.
- AIRS and the assimilated model CarbonTracker agree to some degree. AIRS indicates CarbonTracker transport is too “strong”.
- Of concern, our low SH ocean CO_2. That is also where our day/night differences are largest.
- Some agreement with preliminary SCIAMACHY data. SCIAMACHY unreasonably low at times??? (Will discuss with Bremen.)
- Need to generate, and save, gridded Jacobians for proper comparison to CarbonTracker (or other models).
- Like to improve clear yield in NH winter, or move to cloud-cleared radiances??

250 mbar (Chahine) vs 450 mbar (UMBC) CO_2

250 mbar



450 mbar